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SOLAR ENERGY SYSTEM

Field of the Invention

The present invention relates to a solar energy system and, in particular, to a solar energy system for use in buildings which enables hot air to be generated for space heating, with the optional addition of either heat to be generated for hot water heating, and/or electricity to be generated from photovoltaic cells, or both.

Background Art

It has long been known to provide solar collectors on the roofs of buildings for the purpose of heating hot water and such collectors are well known, and generally unsightly, additions to the roofs of many buildings. This is particularly the case in Australia where solar radiation levels are relatively high. Similarly, it is also well known to provide photovoltaic cells for the generation of electricity from solar radiation and such cells are in widespread use, particularly in rural and outback Australia in locations remote from power generation stations. In particular, in recent years such installations have been favoured over the costs of maintaining lengthy power transmission lines.

Similarly, it is also known, although much less widely implemented, to use solar radiation for the purpose of generating space heating, that is heating the interior of buildings. Although such space heating systems are known, for various reasons they have not found widespread commercial acceptance and are therefore comparatively rare.

Hitherto, if the owner or designer of a building wished to utilize any two, or all three, of the above described systems, then individual stand alone systems would be installed which would not in any way co-operate with each other. Thus, for example, the collectors for heating hot water would be entirely separate installations from the photovoltaic cells used to generate electricity.

Object of the Invention

The object of the present invention is to overcome the abovementioned disadvantage and provide a solar energy system which provides space heating and, if desired, either or both of heating and electricity generation can be integrated within the one overall system, and thereby utilize common component parts.

Summary of the Invention

In accordance with a first aspect of the present invention there is disclosed an air duct having a thermal solar absorber formed on one (upper) surface of said duct and in thermal communication with the interior of the duct, said absorber having a transparent pane through which said duct upper surface can be illuminated by solar radiation with a stagnant atmosphere between said pane and said duct upper surface, wherein said pane and said duct upper surface are substantially co-extensive, said duct has at least one inlet and at least one outlet, the periphery of said pane substantially overlies said inlet(s) and outlet(s), and the intended flow of air through said duct below said pane is substantially unidirectional.

In accordance with a second aspect of the present invention there is disclosed a modular set of a plurality of the above described air ducts each having a connection to permit same to be connected in series, or in parallel, or both.

In accordance with a third aspect of the present invention there is disclosed a solar energy system for a building having an exterior surface exposed to solar radiation, said system comprising a plurality of the abovementioned air ducts mounted on said surface to receive said solar radiation, and an air/liquid heat exchanger in thermal communication with at least one duct interior and connected with at least one heat absorbing load.

In accordance with a fourth aspect of the present invention there is disclosed a building having installed therein the abovementioned solar energy system.

In accordance with a fifth aspect of the present invention there is disclosed a method of sealing adjacent air ducts in an array of air ducts forming a thermal solar

collector, said method comprising carrying out, not necessarily in sequence, the steps of:

(i) inclining to a substantially like extent at least one pair of adjacent side walls of at least one pair of said ducts,

(ii) locating an opening in each said adjacent side wall,

(iii) aligning said openings,

(iv) interposing between said adjacent side walls a strip of resilient material which extends in a loop around the periphery of each said opening, and

(v) moving one of said pair of ducts vertically with respect to the other of said pair of ducts to thereby generate a compressive horizontal component force which compresses said strip to thereby seal said openings.

In accordance with a sixth aspect of the present invention there is disclosed a method of joining cells in an array of solar thermal absorber cells in a water shedding arrangement on an inclined roof, said method comprising the steps of:

(i) forming each said cell with a transparent upper surface which is substantially co-extensive with said cell,

(ii) forming an overlap portion at one longitudinal edge of each said cell,

(iii) arranging said cells in columns and rows to form said array on said inclined roof with said one longitudinal edge lowermost, and

(iv) overlapping said one longitudinal edge of each cell with the opposite longitudinal edge of the longitudinally adjacent cell.

Brief Description of the Drawings

Embodiments of the present invention will now be described with reference to the drawings in which:

Fig. 1 is a plan view of a prior art thermal solar collector used to provide hot air for space heating,

Fig. 2 is a transverse cross-section taken along the line II-II of Fig. 1.

Fig. 3 is a schematic perspective view of a building which has installed therein the integrated solar energy system of a first embodiment,

Fig. 4 is a perspective view of the solar collector array incorporated in the system of Fig. 1,

Fig. 5 is a perspective view of a single modular duct unit used in the array of Fig. 4 and incorporating a thermal solar absorber in its upper surface,

Fig. 6 is a partial transverse cross-sectional view through a number of the ducts of Figs. 4 and 5 showing the side by side interconnection of the ducts,

Fig. 7 is a partial longitudinal cross-sectional view through the collector array of Fig. 4 showing how the upper surface of the absorbers are overlapped so as to provide a water shedding arrangement,

Fig. 8 is a schematic circuit arrangement of the integrated solar energy system of the first embodiment showing the possible flows of hot air, hot water and electricity,

Fig. 9 is a schematic diagram illustrating the compact nature of an integrated system of a second embodiment, and

Fig. 10 is a schematic circuit arrangement of the embodiment of Fig. 9.

Detailed Description

As illustrated in Figs. 1 and 2, conventional thermal solar absorber for heating hot air take the form of a collector box 200 having a glass top 201, side walls 202 and an insulated base 203. Located within the box 200 are two opposed sheets 205, 206 generally formed from profiled roofing material. The opposed profiles define a number of parallel ducts 210, 211, 212, ... 219 which are joined end to end by U-shaped insulated manifolds 220 located exterior of the collector box 200. As indicated by arrows in Fig. 1, a serpentine flow path is created with air flowing through each of the ducts 210, 211, 212,.... 219 in sequence between an inlet 225 and outlet 226.

Located between the glass top 201 and the upper sheet 205 is a stagnant air space which insulates the ducts 210, 219. The upper sheet 205 forms the heat absorbing surface.

This prior art arrangement suffers from various efficiency disadvantages including that the area of the actual ducts (210, 211, 212, ...219) is less than the area of the glass top 201. The prior art arrangement also suffers from a number of constructional disadvantages in that each manifold 220 must be sealed to the corresponding ends of the corresponding ducts. There should also be reasonable sealing between adjacent ducts such as 210 and 211. In addition, the entire box 200 needs to be mounted somewhere on a building, for example on the roof of the building, where it receives solar radiation but inevitably also forms a readily observable eyesore. Furthermore, where a number of such boxes 200 are to be connected together, for example in series or in parallel, then the inlets 225 and outlets 226 must be joined together by appropriated insulated manifolds (not illustrated) similar to manifolds 220.

It follows from the foregoing that if an unobtrusive collector is to be formed without the inherent deficiencies of the collector of Figs. 1 and 2, then an entirely new approach to collector construction was required. Furthermore, as will be apparent from the following description improvements in various aspects of the solar energy system other than the collector, enable an improved overall system to be provided.

Turning now to Fig. 3, for a new building 1 an integrated system can be installed during construction, in particular during construction of the roof 2 upon which a solar collector array 3 is installed. In addition, during construction a piping array 6 in this embodiment is installed in the floor 5 which is intended to carry water for the purposes of either heating or cooling the floor 5 and thus moderating the temperature of the interior 7 of the building 1. The interior 7 is also provided with air outlets 51 and inlets 52 to enable the interior 7 to be heated.

The floor 5 is located above a foundation 9 within which is located a corrugated metal water tank 10, or most preferably an in ground tank fabricated from concrete (not illustrated) the primary function of which is to store potable water. However, the tank 10 having been purchased can also be used to constitute a reservoir of cold water. The building 1 is also provided with a hot water service 11, which is essentially an insulated water tank, and a heat source 12 which in the preferred embodiment is a reverse cycle air conditioning system, but which could merely be a fuel burning heater such as a wood stove, gas or oil fired heater, an electric heater, or similar. A heat bank 50 is also provided. The hot water service 11, heat source 12, and heat bank 50 can be located either outside the building 1 (as illustrated), or inside the building, or under its floor 5 as desired.

The solar collector array 3 of Fig. 3 is formed from a number of individual cells 15 each of which is essentially alike. The collector array 3 is illustrated in more detail in Fig. 4 and the individual collector cells themselves are illustrated in more detail in Figs. 5 and 6.

It will be apparent from Figs. 4-6 that each of the individual collector cells 15 is fabricated as a tubular air duct 16 having an absorber 17 formed on its upper surface. The air duct 16 is preferably formed from pressed sheet metal and, as best illustrated in Fig. 6, has a transverse cross-sectional shape which is a parallelogram which thereby enables the air ducts 16 to be nested side by side as illustrated in Fig. 6. As also illustrated in Fig. 7 the longitudinal cross-sectional shape is also a parallelogram which enables the air ducts 16 to be nested end-to-end as seen in Fig. 7.

The sheet metal from which each air duct 16 is fabricated, is preferably pressed so as to provide two potential transverse openings 18 (Fig. 5) and two potential longitudinal openings 19. Depending upon the intended configuration of the collector array 3 and the intended direction of air flow therethrough, so individual openings 18, 19 are pressed out, or left in situ, prior to assembling the collector array 3.

The upper surface of each collector cell 15 can be formed either as a photovoltaic array 21 (Fig. 4) or as a solar thermal collector 22. The thermal collector 22 essentially takes the form of an upper sheet or pane 23 of glass, polycarbonate or similar transparent material which is spaced from a lower sheet 24 (Fig. 6) which is preferably formed from the metal of the air duct 16. The lower sheet 24 of the collector 22 forms the upper interior surface of the air duct 16. The sheet 24 is preferably treated. The most simple form of treatment is for the upper surface of the sheet 24 to be painted black. The most preferred form of treatment is for the upper surface of the sheet 24 to be coated with a material which absorbs heat and for the lower surface of the sheet 24 to be coated with a material which re-emits heat to the air within the duct 16. An insulating bead 25 extends around the periphery of each of the upper sheets 23 thereby forming a sealed stagnant air volume between the upper sheet 23 and lower sheet 24. Such beads 25 are known per se from the fabrication of double glazed windows. Solar radiation incident on the upper sheet 23 passes therethrough and heats the lower sheet 24 which in turn heats the air in the interior of the duct 16.

As best seen in Figs. 5 and 6, the lower sheet 24 is formed into a single ridge 27 on one side of the cell 15 and into an inverted U-shaped channel 28 on the other side of the cell 15. The ridges 27 and channels 28 are shaped so as to enable the cells to be slidingly engaged as illustrated in Fig. 6 with a ridge 27 of one cell 15 located interior of the channel 28 of the adjacent cell 15.

As seen in Figs. 5 and 6, the base 26 of the duct 16 is provided with a flange 29 through which the shank of a conventional fastener (not illustrated) can pass vertically so as to secure the base 26 to a conventional timber rafter or batten 31 (Fig. 7). Thus as seen in Fig. 6, the left hand duct 16 is first secured and then each duct 16

is secured in turn progressively working to the right as seen in Fig. 6 (and the lower-most row first, and then the next highest row next, as seen in Fig. 7).

Similarly, as regards the longitudinal engagement of the ducts 16, the upper sheet 23 is slightly angled relative to the axis of the duct 16 so as to permit the upper sheets 23 to be overlapped in the manner of conventional roofing tiles as illustrated in Fig. 7. This provides a convenient and water shedding water drainage arrangement which easily mates in overlapping fashion with the conventional material from which the roof 2 is formed. This overlapping is facilitated by a cutaway 29 (Fig. 5) in the upper sheets 23. Although the overlapped sheets 23 are generally waterproof, they can be cracked by the most severe hail. However, since the duct 16 and its upper surface 24 are formed from sheet metal and extend to overlay the surface 24 of the duct 16 below, even severe hail which cracks the sheet 23 will not result in water penetration into the interior of the building 1 via the solar collector array 3.

The air flow passages which extend between the individual collector cells 15 are preferably sealed by means of single sided adhesive, resilient foam tape 20 (illustrated in phantom in Fig. 5) which is located around each of the punched out openings 18, 19. In this way escape of heated air from these cells 15 is prevented. This sealing action is facilitated by the transverse and longitudinal cross-sectional shapes of the ducts 16 each being a parallelogram. As a consequence of this shape, the downward vertical force exerted via the fasteners passing through flange 29 results in the side wall of one duct which lies above the side wall of the adjacent duct, exerting a downward force and thereby generating a horizontal component force which compresses the foam tape 20 interposed between the adjacent side walls by virtue of the tape 20 extending around the periphery of the punched out openings 18, 19. As a consequence, during the installation procedure, adjacent ducts are sealed. In this connection it should be borne in mind that pressure differences between the interior and exterior of the ducts 16 are generally low (being generally only a fraction of an atmosphere).

Finally, as illustrated in Fig. 6, the exterior surfaces of the collector array 3 are preferably insulated with a conventional insulation layer 30. Thermal insulation between adjacent duct cells 16 is, in general, not required.

As best seen in Fig. 4, the solar collector array 3 is provided with input and output ducts 32, 33 which connect to the remainder of the solar energy system to be described in relation to Fig. 8. The input and output ducts 32, 33 illustrated in solid lines in Fig. 4 are those preferably used with, for example, a cathedral ceiling. For conventional ceilings the solid line input and output ducts 32, 33 may interfere with rafters 31 so the input and output ducts 32, 33 illustrated in dotted lines in Fig. 4 are used providing entry and exit of air through apertures (not illustrated) formed in the base 26 of the ducts 16.

As also seen in Fig. 4, fabricated together with the solar collector array 3 is a heat exchanger 35 for liquids formed from an array of copper pipes 36 which pass through preformed apertures 37 as best seen in Fig. 5. As will be explained hereafter, water is passed through the pipes 36 of the heat exchanger 35 and is heated by the hot air present within the interior 38 of the cells 15.

Turning now to Fig. 8, the integrated solar energy system of the first embodiment will now be described. A solar collector array 3 essentially the same as that of Figs. 3 and 4 is provided. The particular array 3 of Fig. 8 has three photovoltaic cells 21 which are shown as being connected in series with a diode 39 and a battery 40 or equivalent. These are intended to schematically illustrate the electrical supply system powered by the photovoltaic cells 21 and used to charge the battery 40. It is to be understood that the battery 40 is merely indicative of the destination for the generated electricity. Instead of a battery 40 a grid interactive inverter can be used. Furthermore, in order to ensure that those cells 15 having photovoltaic cells 21 are cooled to a maximum extent, these cells should be positioned first, or at least early on, in the flow of air through the array 3 (that is, the cells 21 should preferably be adjacent the input 32).

In addition, the hot air/liquid heat exchanger 35 is connected via a pump 42 and valve 107, with a heat exchanger in the hot water service 11. Thus the liquid in the heat exchanger 35, and the potable water in the hot water service 11 do not mix. This enables anti-freeze, or similar, to be used in the heat exchanger 35, if desired. In addition, at night the pump 42 can be turned off to save power thereby allowing the liquid to drain from the heat exchanger 35. Furthermore, the heat exchanger 35 is not

subjected to the relatively high liquid pressures of the building potable water supply. During daylight hours, when the collector array 3 is generating heat, hot liquid passes from the heat exchanger 35 to heat the hot water service 11. During the winter months, hot water is also passed via valve 108 to the piping array 6 which heats the floor 5 of the building 1. However, in the summer months, the valve 108 is closed and another valve 109 is opened thereby allowing a pump 43 to circulate cold water from the under floor water tank 10 through the piping array 6 to thereby cool the floor 5.

Turning now to the hot air flow, a heat bank 50 is provided which preferably takes the form of individual wax "candles" 55 each located within its own tubular plastic housing, the wax undergoing a phase change at typically approximately 40°C. The wax stores heat when passing from a solid to a molten condition and gives out heat when passing from a molten to a solid condition. Other phase change materials including mineral salts can also be used. The heat bank 50 is connected via a blower or fan 44 and dampers or valves 101-106 with the array 3, hot air outlets 51 which lead into the interior 7 of the building 1, an air inlet 52 from the interior 7, and the heat source 12.

When the solar collector 3 is producing heat, hot air passes from the output duct 33 via valve 101 to the heat bank 50 and then passes via the blower or fan 44 through valve 104 to the input duct 32. This flow of air fundamentally stores heat within the heat bank 50 for use at a later time. In addition, during the winter months, if desired, valve 105 can be manipulated so as to allow some of the hot air from the output duct 33 to pass into the interior 7 of the building via the hot air outlets 51. This provides day time heating. During the night time, and at other periods when the solar collector array 33 is not being heated, the valve 104 is closed and the valves 102 and 105 are opened thereby allowing air heated by the heat bank 50 to circulate through the air inlets 52, the valve 102, the heat bank 50 , the vale 105 and the hot air outlets 51.

For those occasions, such as periods of extended rainfall during winter, where an external heat supply is required, the valve 106 can be opened thereby enabling the heat source 12 to supply hot air directly to the heat bank 50.

Turning now to Figs. 9 and 10, a second embodiment of the present invention is illustrated and which is particularly suitable for installation in existing buildings. In all installations it is desirable that the various components of the system be compactly located relative to each other since the volume occupied by the installed equipment should preferably be as small as possible. However, in new buildings there is generally more scope for changing the building itself to better suit the overall system whilst in existing buildings the building itself is generally not changed to minimize expenditure. The second embodiment illustrated in Figs. 9 and 10 makes this minimization of expenditure possible.

In Figs. 9 and 10, the collector 3, building interior 7 and heat source 12 are essentially as before. However, the remaining components to supply hot air can be located within the cabinet 50 used primarily to house the heat bank "candles" 55. In the embodiment illustrated in Figs. 9 and 10, the solar collector array 3 only provides hot air so no hot water is provided nor is any electricity generated. The various flow paths for heated air in Figs. 9 and 10 are essentially as explained above in relation to Fig. 8. However, the compact geometrical relationship of the system components is apparent from Fig. 9.

It will be apparent to those skilled in the art that the above described solar energy system provides hot air for space heating and, if desired, enables the simultaneous provision of electrical energy, and/or heat for hot water. Because the system is integrated, the overall cost is reduced relative to three individual systems because of the utilization of common components. Furthermore, aesthetically the solar collector array 3 is quite unobtrusive and can combine solar thermal absorbers and photovoltaic cells in an aesthetically pleasing manner. Further, the modular nature of the array and the sealing of the individual cells of the array make for both inexpensive construction and quick and inexpensive installation.

In addition, because the photovoltaic arrays 21 have their lower surfaces cooled by the extraction of heat into the corresponding ducts 16, the electrical output of the photovoltaic arrays 21 is increased.

The foregoing describes only some embodiments of the present invention and modifications, obvious to those skilled in the art, can be made thereto without departing from the scope of the present invention. For example, the number of cells in the array 3 of Fig. 2 can be 4 x 4 or 3 x 5 or other such combinations and not just the 3 x 4 combination illustrated.

The term “comprising” as used herein is used in the inclusive sense of “including” or “having” and not in the exclusive sense of “consisting only of”.